2:32

3:22 with multiple distractions

MSE 170 **Final 03/19/09** **166pts. total**

Exam is closed book, closed notes, closed neighbors

Instruction:

1. *Write your name and student ID on top of page.*
2. *Write legibly.*
3. *Show work as needed to justify answers*
4. *Underline all final numerical answers*
5. *You are provided with a periodic table with electronegativities listed, and an equation sheet (values for constants are on the equation sheet)*

Problem 1 (10 points): one point each

Mark **True (T)** or **False (F)** for the following statements.

1. Metallic bonding is the strongest type of bonding out of the primary bonds. F

2. fcc is a close-packed structure. T

3. Silicon will diffuse faster than carbon through a sheet of iron. F

4. The Burgers vector for an edge dislocation is perpendicular to the dislocation line. T

5. Engineering stress of a material is greater than its true stress. F

6. The electrical conductivity of all materials increases with temperature. F

7. In general, the fracture touchness of a ceramic is greater than that of a metal. F

8. The rate of isothermal transformation of steel from austenite (γ) to pearlite (α ferrite + Fe_3C cementite) increases with increasing temperature. F

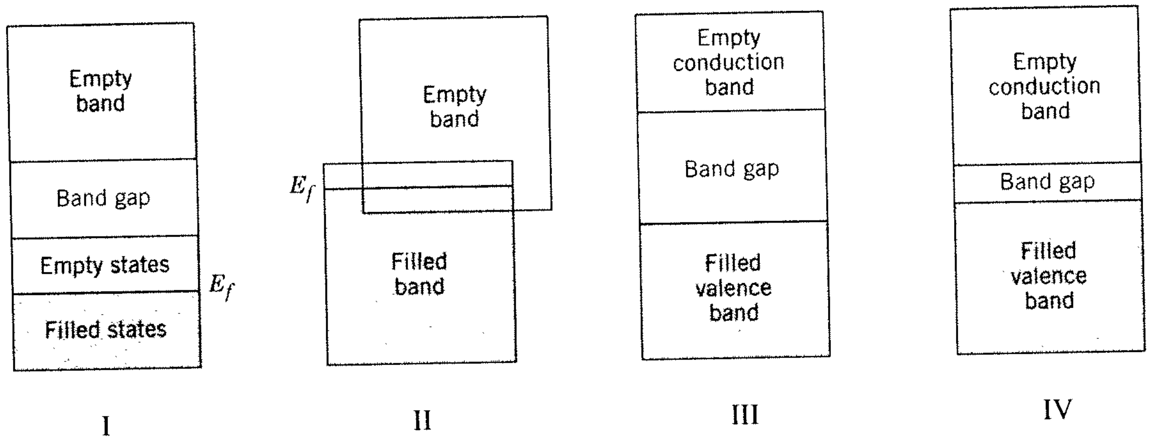
9. Aluminum becomes harder during recrystallization. F

10. The rate of corrosion decreases with temperature. T

Problem 2 (16 points): 2 points each

Multiple choice questions. There is only one correct answer for each question.

1.



From the figure above, what type of electron band structure would you predict for 50 atom% sodium and 50 atom% fluorine?

A I
B II
[✓ C] III
D IV
E I or II

2. From the figure above, what type of electron band structure would you predict for 50 atom% iron and 50 atom% copper?

A I
[✓ B] II
C III
D IV
E I or II

3. From the figure above, what type of electron band structure would you predict for 50 atom% silicon and 50 atom% carbon?

A I
B II
[✓ C] III
D IV
E [illegible] I or II

Mg^{2+}

[illegible] $^{3+}$

3

2.

4. The mobility of electrons above the Fermi Energy, E_f:

A increases with temperature due to increase thermal motion
B are close to the speed of light because the electrons are in the bandgap
C increases with cold work because they move faster on dislocation highways
[✓ D] decreases with temperature due to increased thermal motion
E is less than that of holes because holes have no mass

5. As the molecular weight of a semicrystalline polymer is increased, how will this change the degree of crystallinty?

[✓ A] Decrease, because the chains are more likely to get tangled up
B Increase, because it is more thermodynamically favorable with larger chains
C Not known because crystallinity depends only on the monomer unit shape
D Not known since the degree of crystallinity is dependent on carbon content.

6. In a thermoplastic polymer, adjacent polymer chains are bonded by:

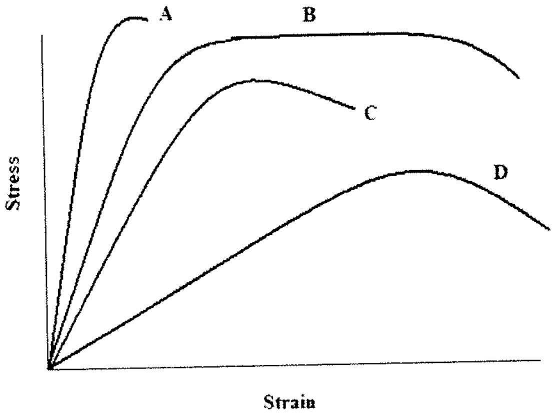
A covalent bonds
B primary bonds
C ionic bonds
[✓ D] secondary bonds
E nothing

7. Above the glass transition temperature, polymers are:

A brittle, because the chains have crosslinked
[✓ B] viscous, because of molecular motion
C rubbery, because of molecular motion
D transparent, because of the molecular motion
E crystalline, because the chains can fold back on themselves

8. Which of the four stress-strain curves to the right show the yield strength?

[✓ A]
B
C
D
E not enough information on the diagram to tell



Problem 3 (20 points):

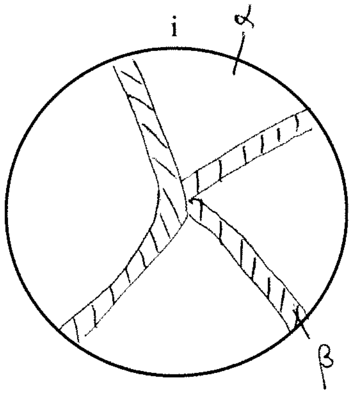
The Cu-Ag phase diagram for this question is shown below.

A. Sketch the microstructure that would form if the following compositions were slowly cooled from liquid to 50 °C.

(i) 95wt% Cu
(ii) 85wt% Ag
(iii) 71.9wt% Ag

2 points each

i



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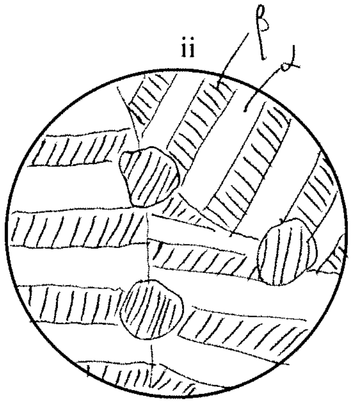
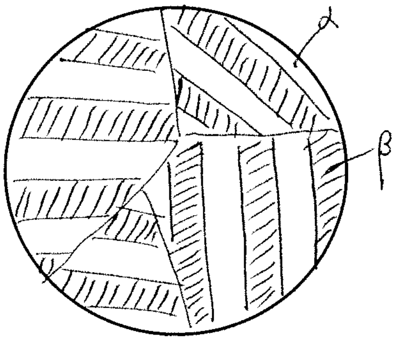
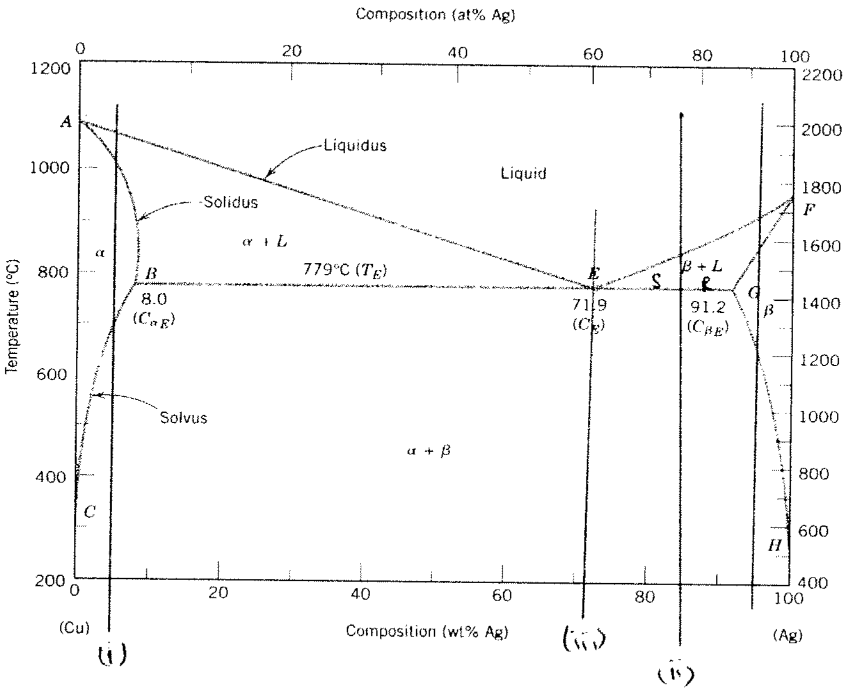


iii





B. The alloys in this part of the question refer to part 3A on the previous page. What is the composition of:

2 points each

(i) solid in alloy A(ii) at 779 °C

$C_\beta = 91.2$ wt% Ag 8.8 wt% Cu

(ii) liquid in alloy A(ii) at 779 °C

$C_L = 71.9$ wt% Ag 28.1 wt% Cu

(iii) solid in alloy A(i) at 779 °C.

$C_\alpha = 5$ wt% Ag 95 wt% Cu.

C. If you heat alloy A(i) from room temperature, at what temperature would melting (formation of liquid phase) start?

1000 °C 2 points

D. What weight fraction of liquid is present in alloy A(ii) at 779 °C.

$$W_L = \frac{R}{R+S} \times 100 \text{ wt\%}$$

2 points for equation

$$= \frac{91.2 - 85}{91.2 - 71.9} \times 100 \text{ wt\%}$$

$$= \underline{32.1 \text{ wt\%}}$$

2 points for value

2 points for unit

-1 point for inappropriate sig. figs.

Problem 4 (20 points): 5 each

Based on the following heat treatments and the given transformation diagram for a steel, determine what phases and amount of each phase are present, starting from 800 °C.

(i) Quickly cool to 240 °C, hold for 100 s, then *slow* cool to 25 °C.

50% martensite

50% coarse pearlite

(ii) Quickly cool to 400 °C, hold for 6 min, then *slow* cool to 25 °C.

50% bainite

50% coarse pearlite

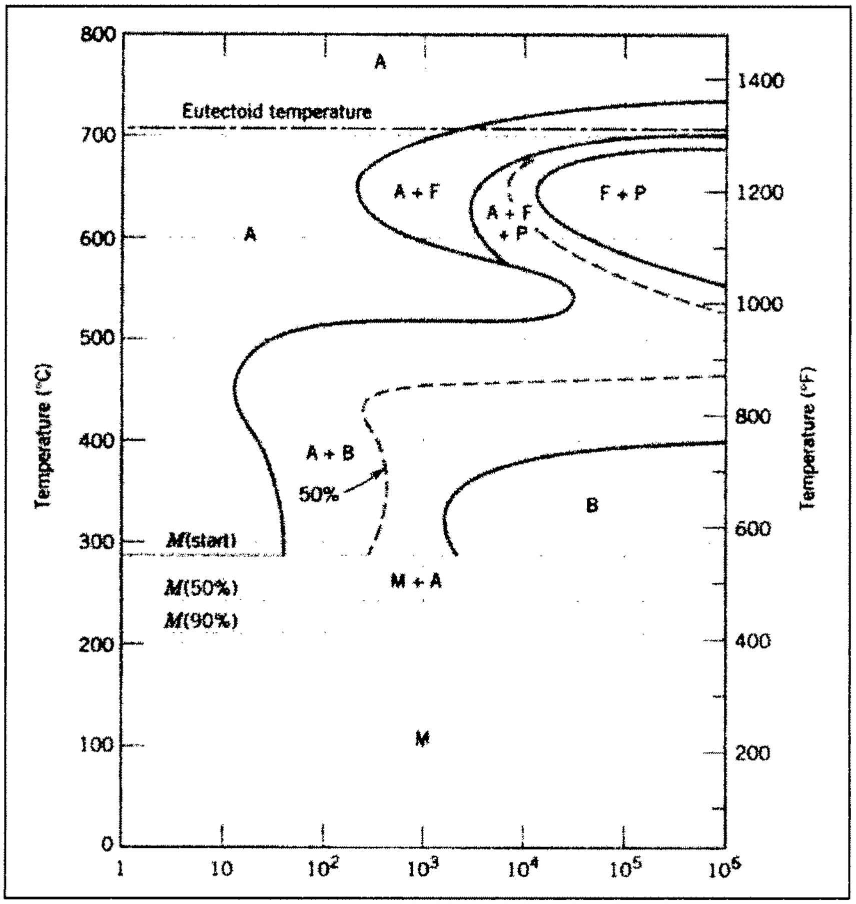
(iii) Quickly cool to 25 °C, then reheat to 250 °C for 1 hour.

100% tempered martensite

(iv) Quickly cool to 600 °C, hold for 1000 s, then quench to 25 °C.

100% martensite.

Fine if very low percentage of ferrite + rest martensite
<5%



Problem 5 (20 points):

A. Describe what Schottky and Frenkel defects are. Also, explain in which class of materials they occur and why.

Schottky - missing cation + anion (2 points)

Frenkel - misplaced ~~[illegible]~~ cation in interstitial site. (2 points)

ceramics - only occurs when you need to take into account the charge neutrality of the system. (2 points for material identification + 2 points for reason)

B. Would you expect Frenkel defects for anions to exist in ionic ceramics in relatively large concentrations? Why or why not?

1 point

No because anion are generally too large to fit into interstitial sites.

1 point for reason

C. What point defects are possible for MgO as an impurity in Al_2O_3? How many Mg^{2+} ions must be added to form each of these defects?

Mg^{2+} substitution for Al^{3+} results in loss of one positive charge. Either need to increase no. of cations or remove anion 2 points

$\Rightarrow$ cation interstitial or anion vacancy. ← 2 points each

2 points each

Cation interstitial: For every three ~~[illegible]~~ Mg^{2+} substitution, have one Al^{3+} interstitial.

Anion vacancy: For every two Mg^{2+} substitution, create one O^{2-} vacancy.

Problem 6 (20 points):

Briefly explain how each of the following influences the tensile or yield strength of a semicrystalline polymer and why:

A. Molecular weight

Increase with increasing MW. ②

Greater chain entanglement. ②

B. Degree of crystallinity

Increase with increasing degree of crystallinity. ②

Increased degree of crystallinity means that there are ② greater intermolecular forces. Greater forces require greater strengths.

C. Deformation by drawing (drawing is when the polymer is deformed while under tension ie. stretched).

Increase with increased drawing. ②

More linear polymers can stack better leading to greater intermolecular forces. ②

and cool to room temperature

D. Annealing (heating polymer below its melting temperature) of an underformed material.

Increases with annealing. ②

Annealing allows movement of polymer chain to realign.

⇒ Improved stacking ⇒ increased intermolecular forces ②

⇒ require greater stress to deform.

E. During the winter months, the temperature in some parts of Alaska may go as low as -55 °C. Of the elastomers, natural isoprene, styrene-butadiene, acrylonitrile-butadiene, chloroprene, and polysiloxane, which polymers would be suitable for automobile tires under these conditions? Which polymers would be suitable for Seattle?

	Elongation (%)	**Useful temperature range (°C)**
Natural isoprene	500-760	-60 - 120
Styrene-butadiene	450-500	-60 - 120
Acrylonitrile-butadiene	400-600	-50 - 150
Chloroprene	100-800	-50 - 105
Polysiloxane	100-800	-115 - 315

③ Alaska: Natural isoprene, styrene-butadiene, polysiloxane

Other polymers would be too brittle.

② Seattle: All of them.

Problem 7 (20 points)

A. Name two advantages a fiber strengthened polymer matrix composite has compared to a polymer on its own.

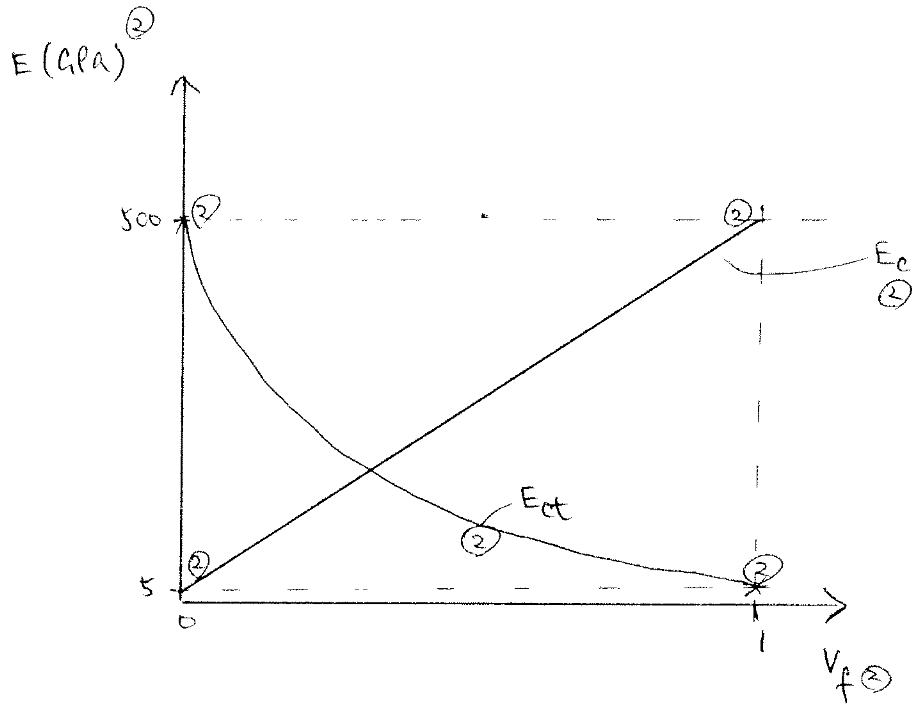
- Increased strength
- Increased hardness
- Increased resistance to the environment

} any two. ② each

B. Sketch a plot of the elastic modulus vs. volume fraction of fibers in the longitudinal direction and the transverse direction for a unidirectional carbon fiber epoxy composite. The properties of the carbon fiber and epoxy are shown below. You do not have to calculate every data point on the curves, but you need to have the values for the maximum and minimum values for elastic modulus.

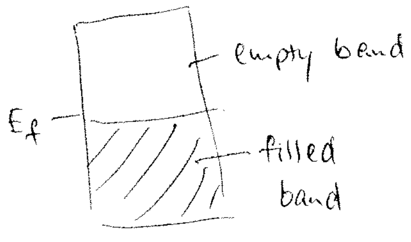
Property	Carbon fiber	Epoxy
Strength	4 GPa	20 MPa
Failure strain (%)	0.1 %	5%
Elastic Modulus	500 GPa	5 GPa

$E_{cl} = E_m V_m + E_f V_f$



Problem 8 (20 points):

A Explain why metals are conductive. Draw ~~Use~~ band structures to do this. ②



②

The left shows the band structure of a metal.

For conduction to occur, electrons must be excited above the Fermi level.

For metals, since there is no band gap, excitation above the E_f can occur at room temperature.

B An aluminum wire 10 m long must experience a voltage drop of less than 1.0 V when a current of 5 A passes through it. Given that the electrical conductivity of aluminum is 3.8×10^7 $(\Omega m)^{-1}$, calculate the minimum diameter of the wire.

$$\sigma = \frac{I l}{V A} = \frac{5A \times 10m}{1.0V \times A} = 3.8 \times 10^7 \, S$$ ①

$$\underline{A = 1.3 \, mm^2}$$

$$\underline{d = 0.65mm}$$

② ①

−1 point for inappropriate s.f.

C If a metallic material is cooled through its melting temperature at an extremely rapid rate, it will form a noncrystalline solid (ie. a metallic glass). Will the electrical conductivity of the noncrystalline material be greater or less than its crystalline counterpart? Why?

Less. ②

Greater disorder in structure will lead to greater scattering of electrons, decreasing the electron mobility. ②

D The following electrical characteristics have been determined for both intrinsic and p-type extrinisic gallium antimonide (GaSb) at room temperature. Calculate the electron and hole mobilities. (*This comment may confuse some people, but note that n and p are similar for this extrinisic case, so be careful about simplifying the equation.*)

	$\sigma((\Omega m)^{-1})$	n (m^{-3})	p (m^{-3})
Intrinisic	8.9×10^4	8.7×10^{23}	8.7×10^{23}
Extrinsic (p-type)	2.3×10^5	7.6×10^{22}	1.0×10^{25}

2 points for work.

$$\sigma = n|e|\mu_e + n|p|\mu_h$$

These are not the points

$$8.9\times10^4 = 8.7\times10^{23}\, e\,(\mu_e + \mu_h) \quad ①$$

$$2.3\times10^5 = e\,(7.6\times10^{22}\mu_e + 1.0\times10^{25}\mu_h) \quad ②$$

$$\rightarrow 18.9 = \mu_e + 131.6\mu_h \quad ②$$

$$\rightarrow 0.64 = \mu_e + \mu_h \quad ①$$

$$② - ① \quad 18.26 = 130.6\mu_h \Rightarrow \mu_h = \underset{②}{0.14}\ \underset{①}{m^2/Vs}$$

$$\mu_e = \underset{②}{0.50}\ \underset{①}{m^2/Vs}$$

−1 point for inappropriate s.f.

Problem 9 (20 points)

A. Corrosion is defined as the destructive an unintentional attack of a metal, and it is an electrochemical reaction. Would you expect iron to corrode in water of high purity? Why or why not?

No ②

Need ions to be present for an electrochemical reaction to occur ②

B. Suggest an appropriate class of materials for each of the following applications, and, if necessary, recommend corrosion prevention measures that should be taken. Justify your answer.

Any sensible explanation is fine.

(i) Laboratory bottles to contain relatively dilute solutions of nitric acid.

Ceramic

Polymer

(ii) Barrel to contain benzene.

Ceramic

Polymer

(iii) Pipe to transport *hot* alkaline (basic) solutions.

Metal with cathodic coating

(iv) Underground tanks to store large quantities of high-purity water.

Metal with cathodic protection on outside.

Any sensible material (only need one)
+ any sensible reason is fine.
2 points for choice of material
2 points for reason.

$$\%ionic = \left\{1 - e^{-0.25(X_A - X_B)^2}\right\} \times 100$$

$$N_v = Ne^{\left(-\frac{Q_v}{kT}\right)}$$

$$J = -D\frac{dC}{dx}$$

$$\nu = -\frac{\varepsilon_x}{\varepsilon_z} = -\frac{\varepsilon_y}{\varepsilon_z}$$

$$\tau_R = \sigma \cos\lambda \cos\phi$$

$$\sigma_m = 2\sigma_0\left(\frac{a}{\rho_t}\right)^{1/2}$$

$$K_c = Y\sigma_c\sqrt{\pi a}$$

$$M_w = \sum w_i M_i$$

$$\frac{1}{E_{ct}} = \frac{V_m}{E_m} + \frac{V_f}{E_f}$$

$$\sigma = n|e|\mu_e + p|e|\mu_h$$

$N_A = 6.022 \times 10^{23}$ atoms/mol

R = 8.314 J/molK

F = 96,500 C/mol

$$N = \frac{N_A \rho}{AW}$$

$$J = \frac{M}{At}$$

$$D = D_0 e^{\left(-\frac{Q_d}{RT}\right)}$$

$$\%EL = \left(\frac{l_f - l_0}{l_0}\right) \times 100$$

$$\%CW = \left(\frac{A_f - A_0}{A_0}\right) \times 100$$

$$\sigma_c = \left(\frac{2E\gamma_s}{\pi a}\right)^{1/2}$$

$$M_n = \sum x_i M_i$$

$$E_{cl} = E_m V_m + E_f V_f$$

$$\Delta V = \left(V_2^0 - V_1^0\right) - \frac{RT}{nF}\ln\frac{\left[M_1^{n+}\right]}{\left[M_2^{n+}\right]}$$

$$\rho = \frac{1}{\sigma} = \frac{VA}{Il}$$

$k = 1.38 \times 10^{-23}$ $m^2kgs^{-2}K^{-1}$

$= 8.62 \times 10^{-5}$ eV/K

$e = 1.6 \times 10^{-19}$ C

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII			IB	IIB	IIIA	IVA	VA	VIA	VIIA	0
H 2.1																	**He** –
Li 1.0	**Be** 1.5											**B** 2.0	**C** 2.5	**N** 3.0	**O** 3.5	**F** 4.0	**Ne** –
Na 0.9	**Mg** 1.2											**Al** 1.5	**Si** 1.8	**P** 2.1	**S** 2.5	**Cl** 3.0	**Ar** –
K 0.8	**Ca** 1.0	**Sc** 1.3	**Ti** 1.5	**V** 1.6	**Cr** 1.6	**Mn** 1.5	**Fe** 1.8	**Co** 1.8	**Ni** 1.8	**Cu** 1.9	**Zn** 1.6	**Ga** 1.6	**Ge** 1.8	**As** 2.0	**Se** 2.4	**Br** 2.8	**Kr** –
Rb 0.8	**Sr** 1.0	**Y** 1.2	**Zr** 1.4	**Nb** 1.6	**Mo** 1.8	**Tc** 1.9	**Ru** 2.2	**Rh** 2.2	**Pd** 2.2	**Ag** 1.9	**Cd** 1.7	**In** 1.7	**Sn** 1.8	**Sb** 1.9	**Te** 2.1	**I** 2.5	**Xe** –
Cs 0.7	**Ba** 0.9	**La–Lu** 1.1–1.2	**Hf** 1.3	**Ta** 1.5	**W** 1.7	**Re** 1.9	**Os** 2.2	**Ir** 2.2	**Pt** 2.2	**Au** 2.4	**Hg** 1.9	**Tl** 1.8	**Pb** 1.8	**Bi** 1.9	**Po** 2.0	**At** 2.2	**Rn** –
Fr 0.7	**Ra** 0.9	**Ac–No** 1.1–1.7															

← Give up electrons

Acquire electrons →